Title Page

A Comprehensive Approach to Balanced Road Space Allocation in Relation to Transit Priority

Report On A Project To Develop A Framework And Guidelines For Road Space Allocation In Relation To Transit Priority in Melbourne, Australia

Graham Currie, Professor, Chair in Public Transport, Institute of Transport Studies, Department of Civil Engineering, Building 60, Monash University, Clayton, Vic. 3800, AUSTRALIA
Phone: +61 3 9905 5574, Fax: +61 3 9905 4944, Email: graham.currie@eng.monash.edu.au

Majid Sarvi, Ph.D., Institute of Transport Studies, Department of Civil Engineering, Building 60, Monash University, Clayton, Vic. 3800, AUSTRALIA
Phone: +61 3 9905 4968, Fax: +61 3 9905 4944, Email: majid.sarvi@eng.monash.edu.au

***William Young**, Professor, Chair in Civil Engineering, Department of Civil Engineering, Building 60, Monash University, Clayton, Vic. 3800, AUSTRALIA
Phone: +61 3 9905 4949, Fax: +61 3 9905 4944, Email: bill.young@eng.monash.edu.au

*Corresponding author

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Graham Currie, Department of Civil Eng, Monash University, Clayton Vic 3800, Australia.
Majid Sarvi, Department of Civil Eng, Monash University, Clayton Vic 3800, Australia.
William Young, Department of Civil Eng, Monash University, Clayton Vic 3800, Australia.

Abstract.

The re-allocation of available roadspace to provide priority for transit is increasing at a rapid rate worldwide. The case for re-allocation of roadspace to transit is clear where service and passenger volumes are substantial. However at lower volumes, the need is less clear since the benefits to transit are small but the impacts on other road traffic large. This paper summarises the major elements of a research project aimed at defining a balanced framework for roadspace reallocation in relation to transit priority. The framework aims to clarify the trade-offs required in developing transit priority systems in a range of traffic circumstances and to provide a balanced allocation of road space based on the full range of impacts. In particular, the approach focuses on people travel and not vehicle travel. It utilizes advanced traffic micro-simulation approaches to better understand the on-road operational implications of alternative transit priority measures and develops a social cost benefit analysis framework to comprehensively value the benefits and costs of priority measures to transit and traffic travelers. The impacts on general road congestion and wider environmental, economic and social impacts are considered. This paper describes the overall project, initial background research, the evaluation framework used and results to date from the micro-simulation modeling. Future directions in the project are identified.

INTRODUCTION

This paper summarises the major elements of a research project to develop a framework and guidelines for road space allocation in relation to public transport services in Melbourne, Australia. The project is sponsored by the State of Victoria's road authority, VicRoads. VicRoads is responsible for road space allocation in Melbourne, Australia. The project is being undertaken by the Institute of Transport Studies at Monash University.

Melbourne has one of the worlds most extensive tram networks (some 240 route km's or 149 route miles). The vast majority of both tram and bus services share road space with other road users. There are no segregated rights of way for bus and relatively little for tram or light rail. A major motivation for the project is to encourage the development of new transit priority projects for Melbourne's extensive tram, light rail and bus networks, but to do this in a manner which is fair to all road users. The desire for a balanced approach reflects the need to both recognize the congestion relief, environmental and social benefits of transit but at the same time to acknowledge that in many of Melbourne's outer suburbs, transit service frequencies are low whilst general road traffic volumes are substantial and congested. The roadspace management authority (VicRoads) needs to have a coherent, rigorous and open approach to roadspace allocation in these circumstances.

This paper outlines the results of background research undertaken for the project, describes the evaluation framework being developed and presents findings of the simulation modeling. Future directions in the project are then described.

APPROACHES TO ROAD SPACE ALLOCATION AND TRANSIT PRIORITY – A CRITIQUE

There is an expanding research literature examining the types of transit priority treatment and how they should be designed. Numerous guidelines are provided (*1, 2*) and reference is made to bus priority measures in Transport Research Board publications (*3, 4, 5*). The literature shows a bias towards bus rather than tram or light rail priority although there is some limited coverage of the latter (*6, 7*) and local work in Melbourne (*8*). This bias may occur because modern light rail systems tend be designed in their own right of way as a matter of course. It is mainly in older tram systems, such as that in Melbourne, where vehicles operate in mixed road traffic conditions.

Warrants for the provision of transit priority are often provided in relation to the volumes of transit vehicles and passengers. These are almost entirely sourced from experimental or modeling studies (*9*). They rarely use dynamic traffic simulation approaches to determine appropriate priority warrants. An exception to this may be Jepson and Ferreira (*10, 11*) where a semi dynamic approach was developed using TRANSYT and SIDRA.

A major finding from the literature review was that these approaches focus on the immediate travel time trade-offs between transit and non-transit users. This is a simplistic basis for allocating roadspace since:

1. There is little consideration of reliability improvements. Transit priority measures can clearly reduce travel time for transit vehicles, however there is much research to suggest that improving the reliability of these vehicles is a far more important objective. A range of studies (*12, 13, 14*) suggest that passengers value unexpected waiting time as a result of unreliable transit services far in excess of travel time made within vehicles. These sources suggest unexpected delays may be valued between 3 and 12 times more than in-vehicle travel time.
2. Road congestion relief from increased transit ridership is not considered. Improving travel times and reliability of transit services directly increases ridership. This will, at least in part, result in reduced road usage and hence reduced road congestion, reduced road vehicle operating costs, reduced accident costs and also lower environmental impacts.
3. Capital and operating cost implications are not considered. A good deal of the literature (*4,5*) recognizes the benefits transit priority can have on reduced transit vehicle and crew operating resources through faster running times. However the financial benefits of these measures are not a feature of the evaluations which determine transit priority guidelines. Neither it appears are the costs of providing priority systems. Despite the often substantial levels of investment required for segregated rights of way.
4. Route changes may take place due to drivers' perception that alternate routes may be quicker. These changes may result in the more efficient use of less congested elements of the road network.

These findings provide a basis for the development of a more balanced framework for transit priority provision.

OUTLINE FRAMEWORK FOR BALANCED ROAD SPACE ALLOCATION AND TRANSIT PRIORITY

Figure 1 illustrates some of the direct and secondary impacts resulting from the re-allocation of road space to transit. The framework proposed aims to estimate these impacts and use them to identify the preferred allocation of road space. The best allocation lies where all the benefits and costs identified in Figure 1 are optimized for all road users and for society as a whole. Effectively this represents a Social-Cost Benefit based approach where all impacts are valued and assessed quantitatively where possible. Qualitative Social Benefits are identified where relevant and will be a part of the overall assessment of the transit priority options where identified.

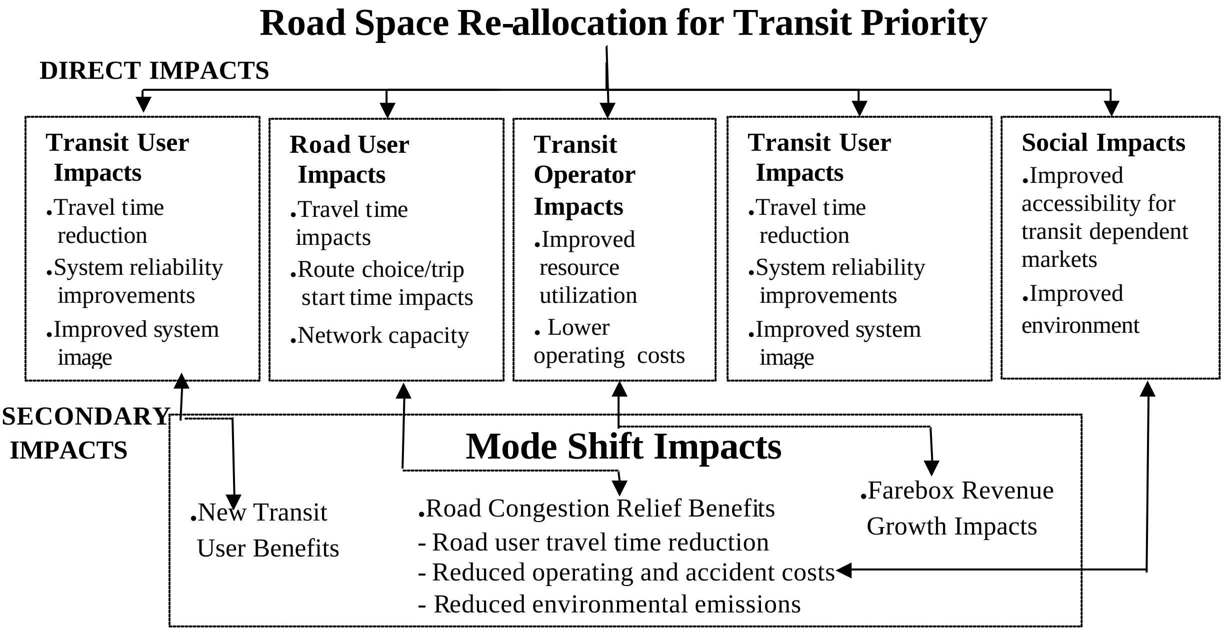


FIGURE 1: Impacts Considered in the Proposed Roadspace Re-allocation Evaluation Framework

The methodology for application of the framework is being developed as the project progresses. Table 1 shows the key elements of the approach being taken.

TABLE 1 : Proposed Methodology : Roadspace Reallocation Impact Estimation

Impact Area	Approach to Estimation	Comments/Sources
Transit User Impacts	Travel time and reliability improvements based on micro-simulation modeling	• Market impacts considered by individual user and a market wide estimate made
Road user Impacts	Travel time and reliability improvements based on micro-simulation modeling	• Separate impacts considered for general, business and road freight
Transit Operator Impacts	Route operations model estimates fleet and crew resource impacts	• Peak vehicle fleet impacts and vehicle km and vehicle hour estimates made for each option tested • Unit operating costs used to identify overall cost impacts
Infrastructure Impacts	Option Costing model	• Infrastructure capital and any operating cost impacts of priority measures identified.
Social Impacts	Qualitative assessment of overall social impacts	• Impacts identified but not valued
Mode Shift Impacts	Mode Shift Forecasting Model	• Uses an elasticity based modeling approach • Externality impacts estimated using unit externality benefit rates identified by the Department of Infrastructure (DoI) Victoria (*17*)

An important part of the direct impact assessment is the use of a traffic micro-simulation model. Paramics (*15*) is used in this study due to its ability to provide reliable replications of public transport and traffic systems. The modeling approach is described in detail in the next section.

The core of the mode shift model is an elasticity-based algorithm which forecasts growth in transit usage based on improvements in transit travel. A generalised cost elasticity approach is used with the various elements of transit travel being weighted based on user perception of their value (*16*). This includes valuation of unexpected waiting time, which is valued at 6 times actual unexpected waiting time (*12, 13, 14*). Only a proportion of new transit users are assumed to be diverted from car travel. The 'externality impacts' of reduced road use are based on values identified by DoI (*17*) see Table 2.

TABLE 2: Values for Externality Benefits of Reduced Road Use (2002-3)

Externality Impacts	Situation	Value (Cents Aust. per reduced road vehicle km)	Source
Congestion Relief Benefits including : • road travel time benefits • reduced vehicle operating costs • reduced road accident benefits	Peak Heavy Congested Area	90	DoI (*17*) based on work by Ogden and Stanley (*18*) estimating congestion relief benefits
	Peak Moderate Congested Area	60	
	Peak Other/Off Peak	16	
Environmental Relief Benefits	All	2.4	DoI (*17*)

TRANSIT AND TRAFFIC VEHICLE OPERATIONS MODELLING

Model overview

Paramics (*15*) is a micro-simulation model used to identify the road operations impacts of alternative transit priority treatments on both transit and other road vehicles. Micro-simulation enables the dynamic representation of traffic flows relative to the movement and stopping patterns of public transport vehicles and vice-versa. In the model, individual vehicles are represented in fine detail for the duration of their entire trip providing accurate traffic flow, transit time and congestion information. It also facilitates the modeling of the interface between driver/vehicle units and transit priority. The model is operated for a range of situations including alternative:

- transit service frequencies and configurations (Light Rail Transit (LRT), tram and bus)
- transit priority designs (shared and exclusive lanes, alternative light phasing)
- traffic circumstances and conditions (road widths and intersections designs at varying levels of traffic flow and congestion).

An original feature of the modeling is the representation of the adaptive traffic light phasing technology, which is in operation in Melbourne. The SCATS system (*19*) is in use in Melbourne and employs dynamic recognition of transit vehicles and active allocation of green time priority for transit.

Application process

A two tiered application process is used for the model including:

1. Case Study Modeling – where a real world corridor is modeled and alternative transit priority treatments and their impacts are considered. In this case the 'base case' represents existing levels of priority.
2. Test Group Modeling – where a series of indicative linked intersection and road configurations are developed and alternative priority treatments examined. Here the base case is a zero priority scenario.

A significant proportion of the modeling work in the project is test group modeling. Although essentially theoretical in nature the design of test groups will be based on typical real world situations. These situations will replicate common intersections and road configurations and will form the basis of extrapolating the evaluation process to allow the evaluation of transit priority on numerous combinations of intersections, road and demand configurations.

The modeling process includes iteration of the runs to obtain a stability of results. The dynamic and random nature of the model can produce a range of results for a given scenario. Understanding the bounds of this range is a key aspect of the analysis. Generally around 10 iterations are undertaken for each scenario to explore the range of results.

Results

Initial modeling work has concentrated on two test groups including tram and bus priority treatments. Figure 2 shows the base case road layout designs in each case. This consists of four-lane divided arterial road with traffic signals at 500 meter spacing. Table 3 provides traffic and geometry characteristics used in the bus and tram applications of the model.

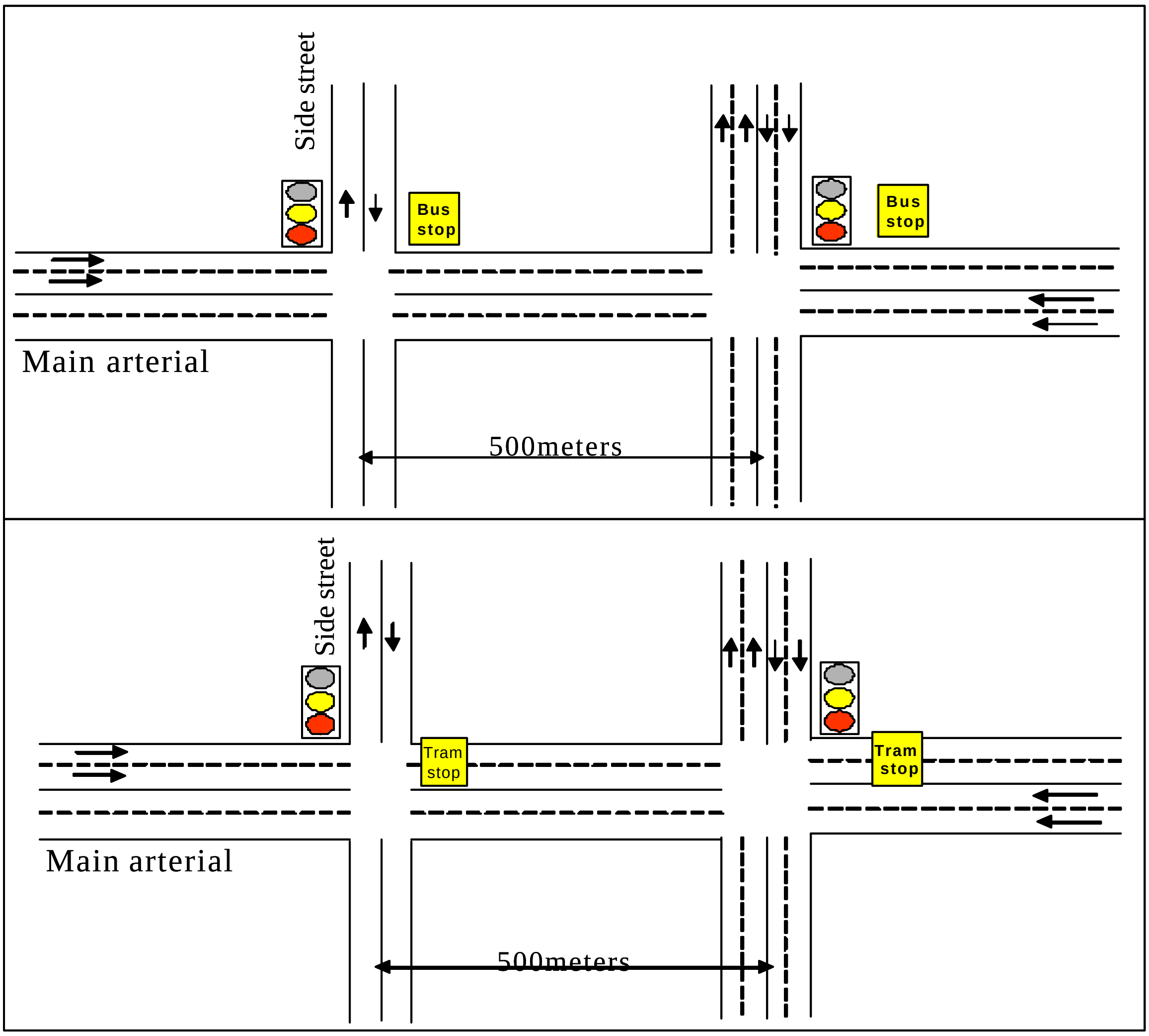


FIGURE 2: Initial Test Group Modeling – Base Case Design

TABLE 3: Micro-Simulation Modeling – Key Traffic and Geometry Assumptions

Road Configuration	• Main road (arterial) 2 by 2 lanes • Minor cross roads at 2 intersections – 1 by 2 lanes and 2 by 2 lanes • No side roads on main road
Intersection Signal Configuration	• Cycle time = 1 minute • Fixed 75% main road green time • No adaptive traffic signal responsiveness
Transit Service	• 5 minute headway • 30 second stop dwell time • Fixed stop locations at departure side of intersections
Road traffic Volumes	• Modeled at volumes of 250, 500, 750, 1,000 and 1,250 vehicles per hour
Percentage commercial traffic	• 20 percent

Modeling examines traffic volumes in a range between 250 and 1,250 vehicles per hour (vph). Tests indicated that above 1,250 vph traffic becomes highly congested resulting in complete break down of flows for all vehicles including transit.

A unique feature of the tram operation modeled in this case is the median operation of trams with passenger boarding from the kerbside. Tram stops are located at the kerb but tram vehicles stop in the median to board and alight passengers. All vehicular traffic behind the tram must stop to enable kerbside passenger movement to and from the tram. Bypassing trams in these situations is illegal. Figure 3 shows an example of this arrangement.

FIGURE 3: Example Kerbside Loading Tram Stop – Down Stream Road Traffic Must Wait for Passenger Boarding and Alighting

Tram Priority Treatments – Initial Results

The impact of introducing a tram lane with various length of set-back (L) from zero (complete tram priority) to 100 meters (see Figure 4) was assessed.

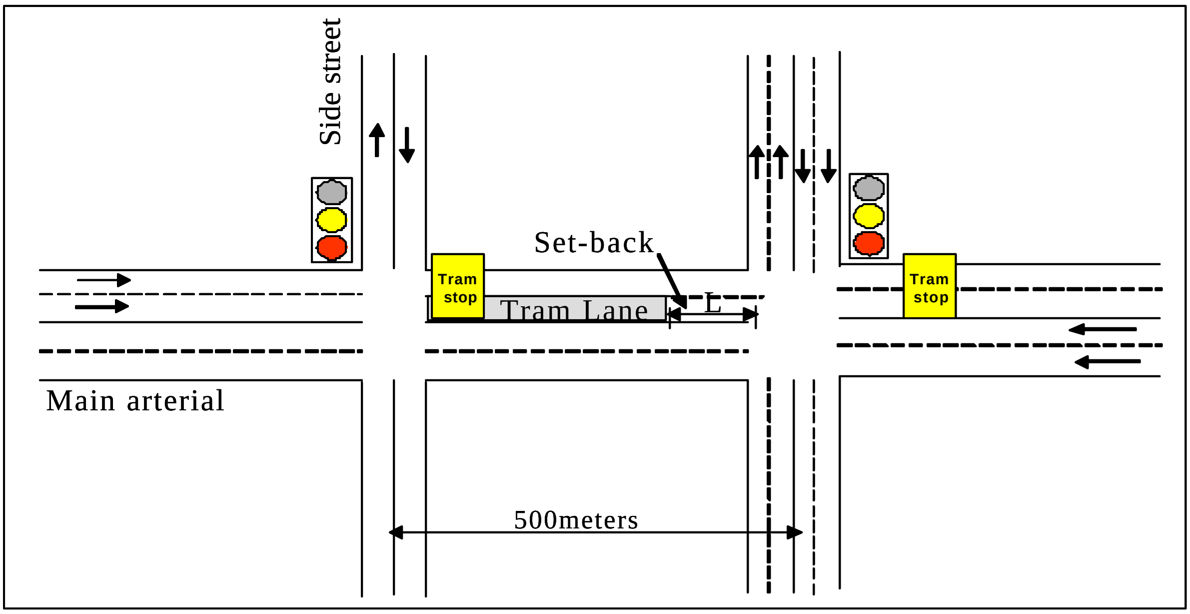
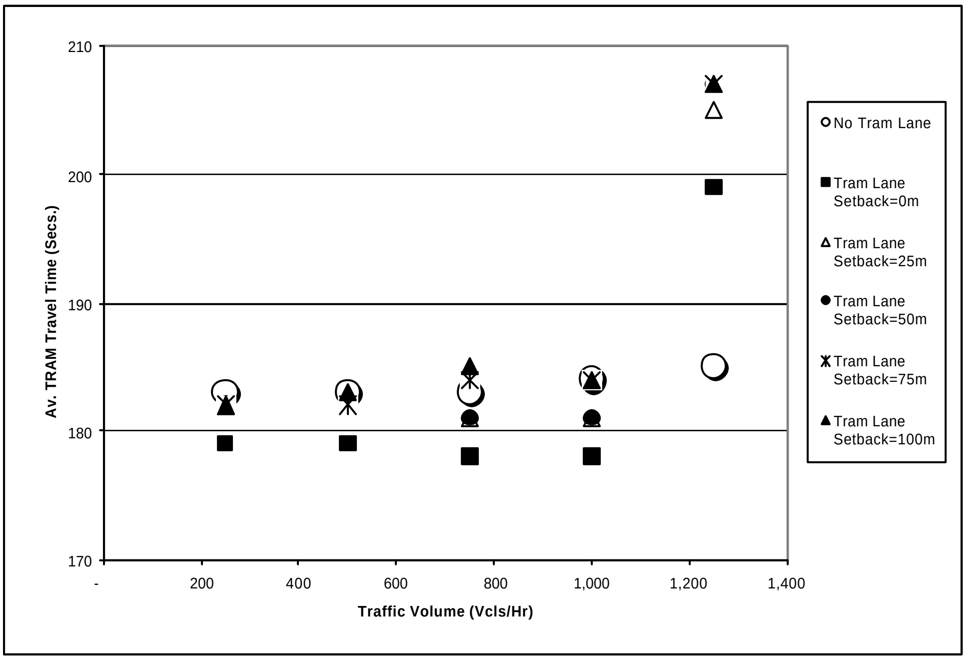


FIGURE 4: Tram Priority Treatment Tests – Median Tram lane with Alternative Setbacks (L)

Figure 5 shows the average travel time impacts on tram vehicles and also general traffic at varying levels of traffic congestion.

TRAM IMPACTS



GENERAL TRAFFIC IMPACTS

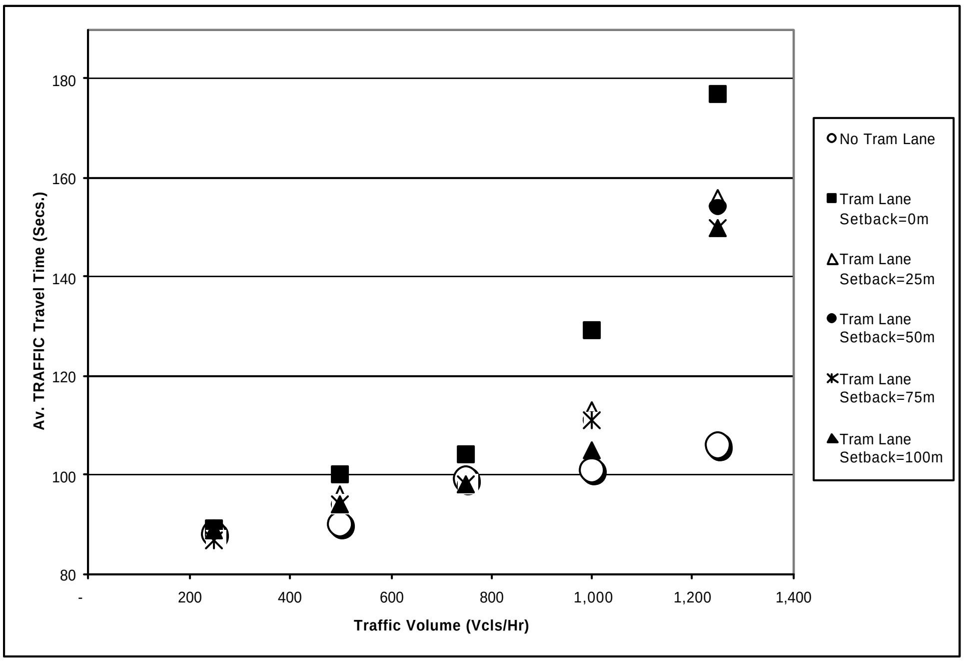


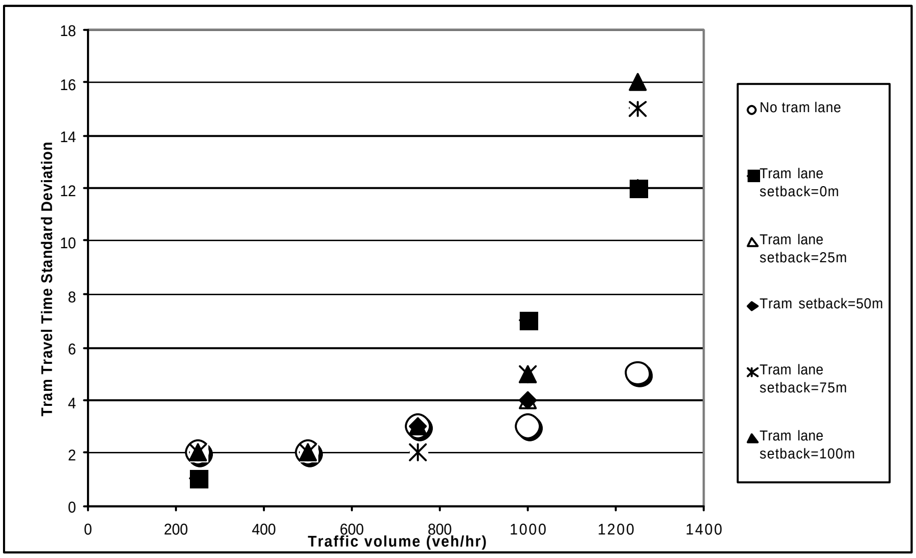
FIGURE 5: Tram and General Traffic Travel Time Impacts – Alternative Tram Priority Treatments

These results illustrate many features of the performance of the road system:

- Firstly average tram and road traffic travel times are different. At a given road traffic level trams are always slower mainly due to the need to slow down and stop at boarding and alighting stops
- At road traffic levels below 1,000 trams receive travel time advantages as a result of the introduction of tram priority lanes. These benefits are generally larger for shorter lane set back lengths.
- Interestingly while there are travel time benefits to tram of priority measures at lower traffic volumes, the impacts on road traffic are not large. It is only where traffic levels reach 1,000 and over that tram priority levels cause significant delays to road traffic. These delays correlate positively with the degree of set back length; the smaller the set back the larger the traffic delays

- An important finding is that at traffic volumes of around 1,250, trams no longer receive benefits from tram priority lanes. This is because queues of road traffic stopping behind trams spill back to downstream intersections and delay the next tram, effectively the traffic flow is in gridlock or breakdown.

The breakdown of traffic flow at high levels of traffic volume is well illustrated by the variability of tram travel times as traffic flow increases (Figure 6).



Note: Standard Deviation of Tram Operating Times by setback and traffic volume option

FIGURE 6: Variability of Tram Operating Travel Times – Alternative Tram Priority Treatments

At traffic flows over 1,000 vph tram lanes of any setback design provide a less reliable set of operating times than having no tram lane at all. Again this is due to the impacts of traffic queues behind the tram affecting trams downstream.

These results suggest that limited allocation of tram lanes in high traffic situations will present difficulties for all road users including trams. However this conclusion is only relevant to the specific circumstances modeled (i.e. with relatively short road sections between intersections).

Bus priority treatments – Initial Results

The impact of introducing a kerbside bus lane with various length of set-back (L) from zero (complete bus priority) to 100 meters was also assessed (see Figure 7).

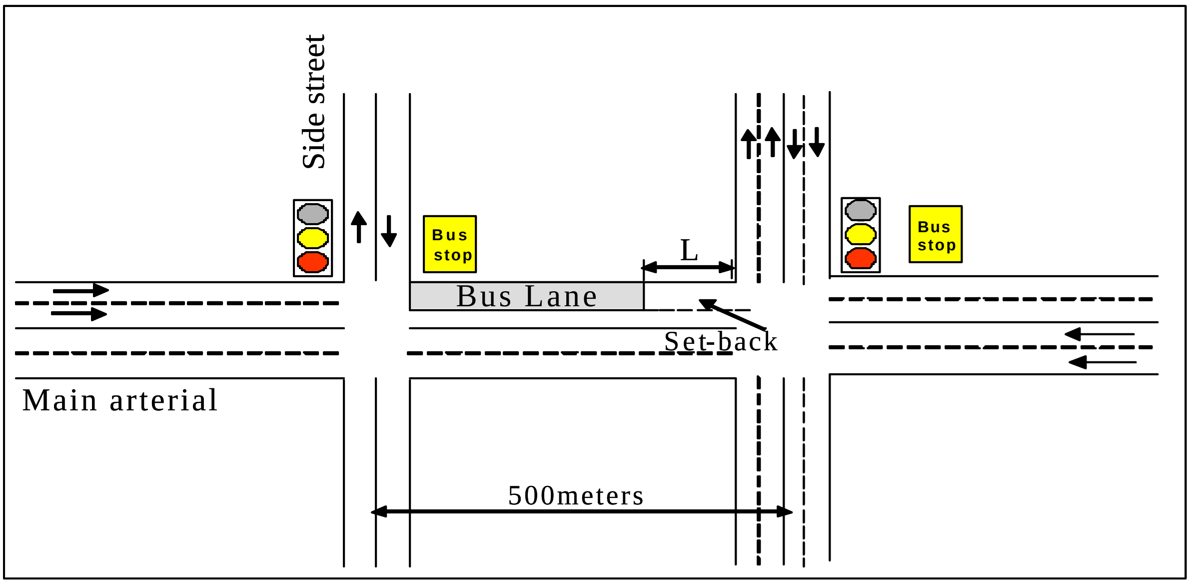
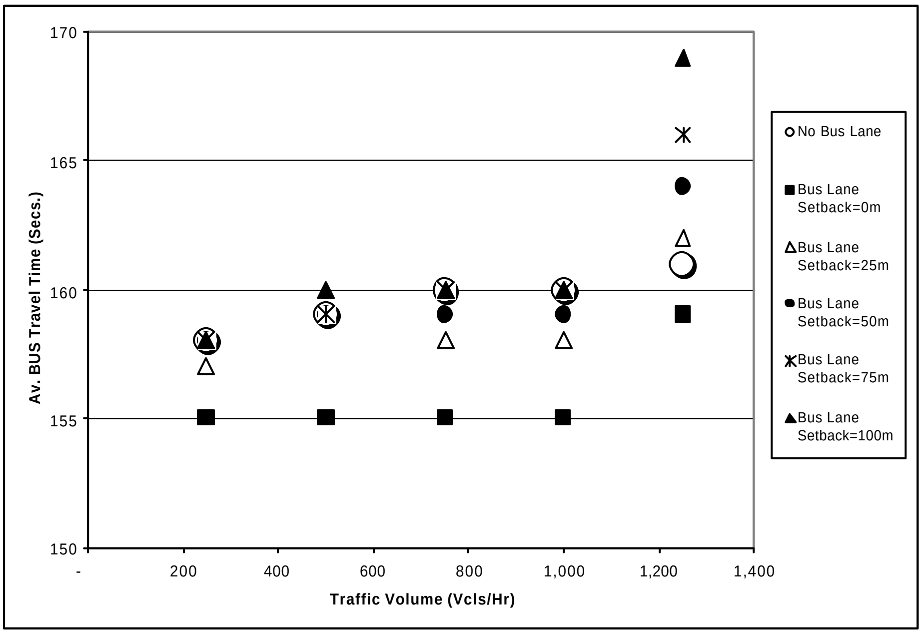


FIGURE 7: Bus Priority Treatment Tests – Kerbside Lanes with Alternative Setbacks (L)

Figure 8 shows the operational impacts on buses and also general traffic at varying levels of traffic volume.

BUS IMPACTS



GENERAL TRAFFIC IMPACTS

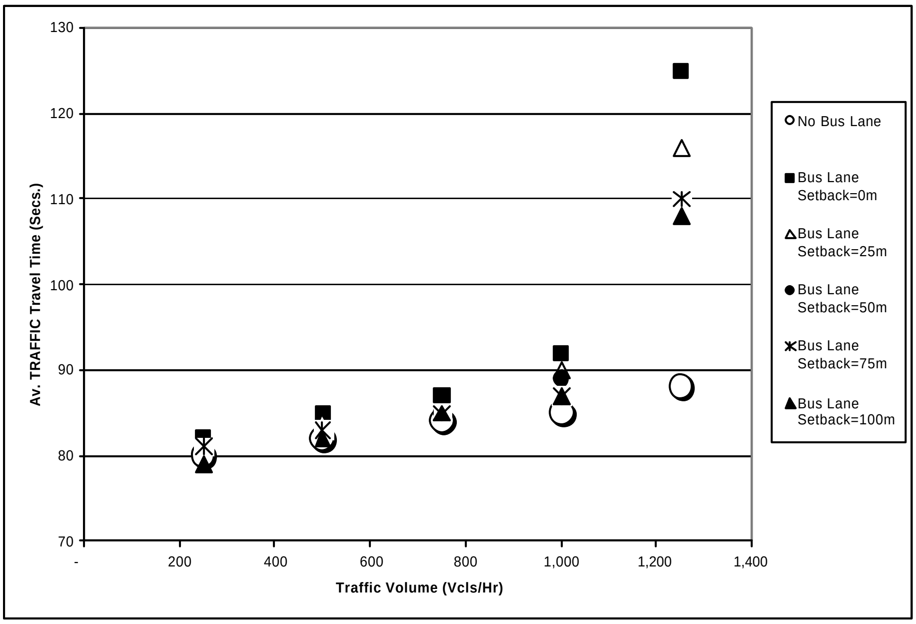


FIGURE 8: Bus and General Traffic Travel Time Impacts – Alternative Bus Priority Treatments

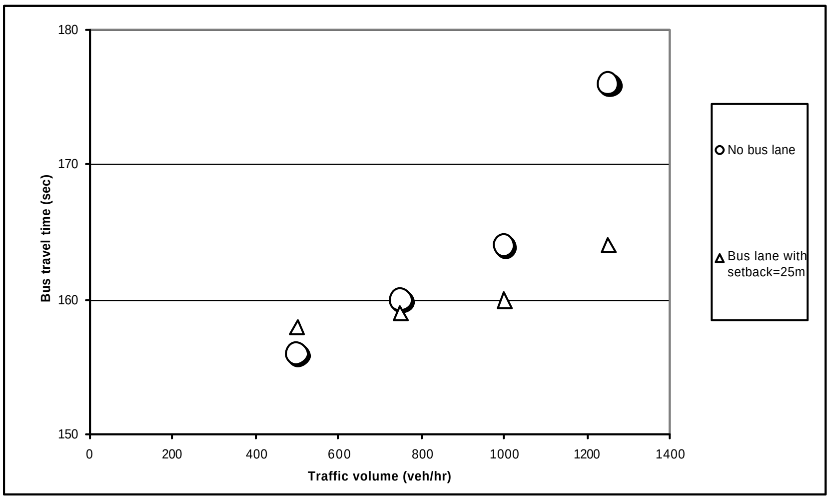
These results show that:

- Compared to Figure 5, buses operate at higher speeds than tram. This is due to better acceleration and deceleration performance of bus which is better than the older Melbourne trams included in this analysis
- Also compared to tram, general road traffic runs faster. These are due to the delays caused by trams using kerbside stops and delaying general road traffic as passengers' board and alight.
- At road traffic levels below 1,000 vph, the general road traffic impacts of the bus lane are relatively minor whilst the benefit to bus, particularly of zero setback lanes, is large
- Much like the tram modeling, traffic volumes above 1,000 vph see traffic flow breakdown. Considerable time delays result for general traffic.
- These delays also affect buses due to traffic queues affecting buses in downstream traffic. There is some suggestion that zero setbacks will still provide some benefit to bus at this volume. However,

these benefits are minor and are probably not within the bounds of significance given the range of variability in the analysis.

An important dimension of the bus situation is the interaction between transit, general traffic and pedestrian movement. Pedestrian interaction with vehicles turning into adjacent roads has particular impact on the performance of bus transit. The effects of pedestrian movements crossing in side streets have been modeled by adjusting the Paramics system to incorporate pedestrian flows. The focus of this analysis is the interaction between left turning traffic and pedestrian crossing movements and the flow on impacts this has on arterial road traffic. This impact is illustrated in Figure 9 where a 30% left turning movements ratio is introduced at intersections. Pedestrian crossing volume is set to 300 per hour (on average 5 pedestrians per cycle cross the side streets).

BUS IMPACTS



GENERAL TRAFFIC IMPACTS

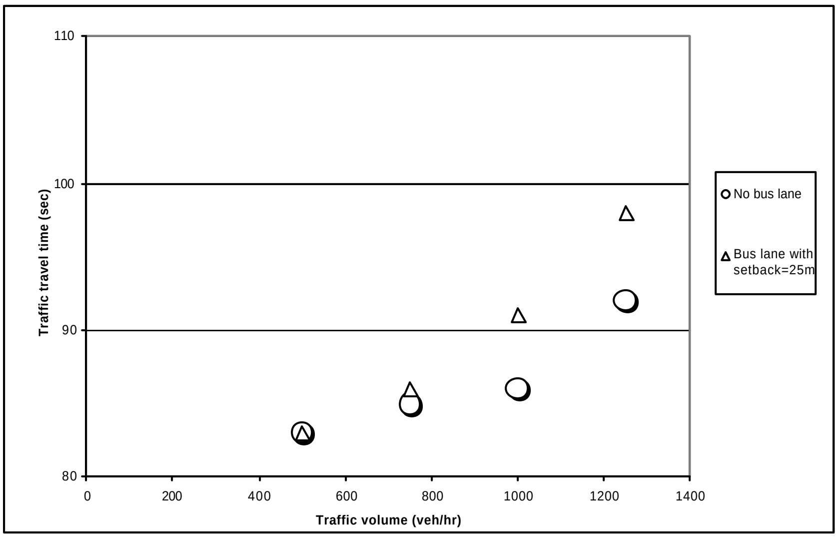


FIGURE 9: Bus and General Traffic Travel Time Impacts – Introduction of Vehicle Turning And Pedestrian Crossing Movements

Comparison of Figure 8 with Figure 9 shows that :

- At low traffic volumes (below 1,000 vph), bus and traffic travel times are similar with and without bus priority regardless of the levels of turning movements and pedestrian flows
- However at higher traffic volumes (over 1,000 vph), bus travel times are larger when turning/pedestrian flows are present. This demonstrates the action of turning traffic delaying buses
- The benefit of a bus lane is significantly larger at very high traffic volumes (1,250 vph) when turning movements and associated pedestrian flows are present. In Figure 8, where turning and pedestrian movements were low, traffic flows were in breakdown. Buses ran slower even with a bus lane. This

suggests that significant turning movement delays may make bus lanes more viable in high traffic conditions.

Observations on Modeling Findings

The initial results have proven the operational form of the model to be suitable for the purposes of the project. The findings have been illustrative of the dynamic nature of traffic flows in relation to the movement of transit vehicles on a network. The test group approach is a very valuable approach to developing guidelines and as input to the evaluation process. However, the test group modeling presented in this paper is only a limited form of representation of the traffic system. The focus on small road sections limits opportunities for alternative route choice decisions to be made and neglects wider operational problems that transit managers have along the total length of the route and for the network as a whole. The preliminary modeling has included sensitivity testing of alternative intersection turning flows and the impacts of alternative pedestrian crossing influences on turning traffic movements. In particular, modifications to the Paramics software have been undertaken to represent alternative pedestrian crossing volumes. Analysis has suggested that intersection turning movements and associated pedestrian flows have an important influence on the impacts of transit priority on all road users.

CONCLUSIONS AND FUTURE RESEACH

This paper has summarized the findings of a project to develop a balanced road space allocation framework for the introduction of transit priority. The main aim of the project is to identify a full range of travel, environmental and social impacts of introducing transit priority to ensure its introduction has a good net impact. A review of research in this area has identified that the immediate travel time trade-offs between transit and road users has been at the core of previous approaches to road space allocation assessment. This is considered a limited approach to the issue. A new framework including the addition of service reliability impacts, transit operator impacts, infrastructure costs, social and environmental impacts and wider mode shift impacts is proposed. Microsimulation traffic modeling is the main tool used to assess road traffic operational impacts of various transit priority measures. Preliminary testing of the traffic operations model has identified that representation of the dynamic nature of traffic flows around transit vehicles and priority measures is an essential requirement to fully understand the impacts of priority treatments. The project is to proceed with economic assessment of the priority treatments tested and to an expanded horizon of case study and test group models. The project will continue into late 2004.

More specifically, future work in the project will have two major case study corridors modeled (one tram and the other bus) and over 30 test group scenarios are envisaged. To better focus the design of test group modeling a typology of intersection layouts within Melbourne is being developed. Test group design will be developed around the most common intersection, and associated transit, configurations.

Economic assessment of the operational modeling is yet to begin in the project. However it is envisaged that a full assessment of the case studies and a large number of the key test groups will be assessed using the methodology identified.

The final output of the assignment will be a series of guidelines for the introduction of transit priority in various traffic conditions. These will be developed late in the assignment as the results of the modeling are finalized.

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